Reprinted from the Preprint Volume of the Fifth Conference on Climate Variations, October 14-18, 1991, Denver, Colo. Published by the American Meteorological Society, Boston, Mass.

P1.13

A Regional Precipitation Index for Lake Michigan-Huron Water Level Fluctuations

Frank H. Quinn

Great Lakes Environmental Research Laboratory, NOAA
Ann Arbor, Michigan 48105-1593

1. INTRODUCTION

Great Lakes water level fluctuations are extremely important for the nation's water resources and for natural hazard considerations. The hydrologic regime of Lake Michigan-Huron has changed over the past 150 years due to changes in the outlet channels, major land use changes in the basin, and water diversions into and out of the upper Great Lakes. Thus, recorded Lake Michigan-Huron water levels would not be replicated by a return of the past climate regime. As precipitation is the primary forcing function for Great Lakes water levels, it is helpful to examine past trends in precipitation relative to recent hydrologic conditions to assess the potential for future high and low water level regimes. The Great Lakes with their large surface areas and constricted outflows moderate the impacts of yearly variations in precipitation with critical lake levels usually occurring only during periods with several years of well-below or well-above average precipitation. An analysis of Lake Michigan-Huron lake levels and upper Great Lakes basin precipitation indicates that the peak lake levels are best correlated with a 5-year weighted precipitation index. This index provides an excellent perspective on changes in the regional Great Lakes precipitation climate and the resulting lake level fluctuations.

2. DATA

Great Lakes water level data have been recorded at many sites since the early 1800's. For Lake Michigan-Huron the record goes back to about 1819 (Quinn and Sellinger, 1990) with the primary data set consisting of monthly mean values for the period 1860-present (National Ocean Service, 1991). For this study the July monthly mean water level recorded at the Harbor Beach gage was chosen as the lake level of interest. Lake Michigan-Huron's average high water level occurs during the month of July.

The precipitation is represented by an annual lake-year time series of weighted upper Great Lakes precipitation. A lake year is defined as the months of August through July and has been found to be useful for Great Lakes studies. The weights for the precipitation time series are .19, .67, and, .14 for Lakes Superior, Michigan-Huron and Erie, respectively. This weighted precipitation reflects the relative contribution of the system precipitation on the water levels for Lakes Michigan-Huron and Erie. The basic data is the monthly overland precipitation data for the basins of Lakes Superior, Michigan-Huron, and Erie (Quinn, 1981; Quinn and Kelley, 1983). The data have recently been revised for the period 1860-1900 and updated through 1988.

3. PRECIPITATION INDEX

The weighted annual precipitation time series for the upper Great Lakes is shown in Figure 1. This data was used in a regression

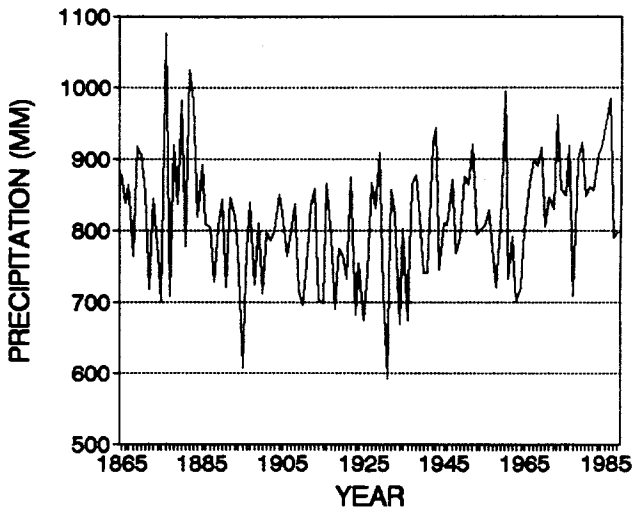

Figure 1. Annual upper Great Lakes weighted precipitation.

analysis with the July Lake Michigan-Huron lake levels to determine a series of weights to be applied to the present and antecedent annual precipitation to yield the best correlation between annual lake-year precipitation and July water levels. It was determined that a 5-year weighted average best fit the data. The regression

$$Pw_i = .33P_i + .28\,P_{i-1} + .16\,P_{i-2} + .13\,P_{i-3} + .10\,P_{i-4}$$

where: Pw_i is the weighted annual precipitation at year i
P_i is the annual upper Great Lakes precipitation at year i.

was based upon the period 1936-1988 which appeared to be relatively homogeneous from the analysis. Time series prior to 1936 appears to be affected by major changes in the hydrologic

regime. The index, Figure 2, is computed as the difference of the 5-year weighted annual precipitation and its mean.

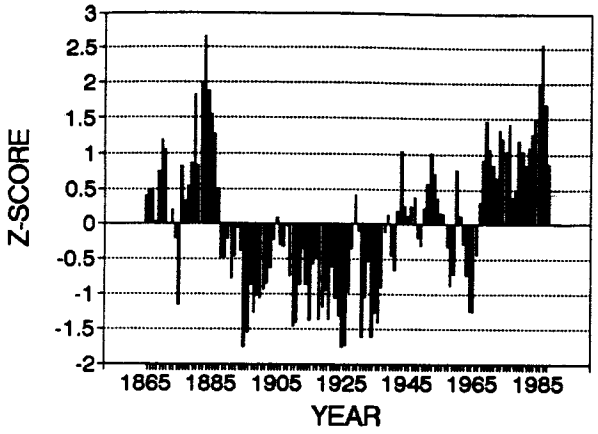

Figure 2. Great Lakes precipitation index.

Of particular interest are the high index values centered about 1883. They indicate the potential for record high lake levels similar to those occurring in 1986. Also of interest is the prolonged period of very low index values during the last of the 19th century and the early to mid 20th century indicating the potential for lake levels lower than the most recent low water period of 1963-1965. This is particularly important because the last 20 years of high water levels have reduced the perspective for low lake levels which were prevalent during a good portion of this century.

The relationship between the precipitation index and the Lake Michigan-Huron water levels is shown in Figure 3. A very good correlation exists between the years of 1936 and present.

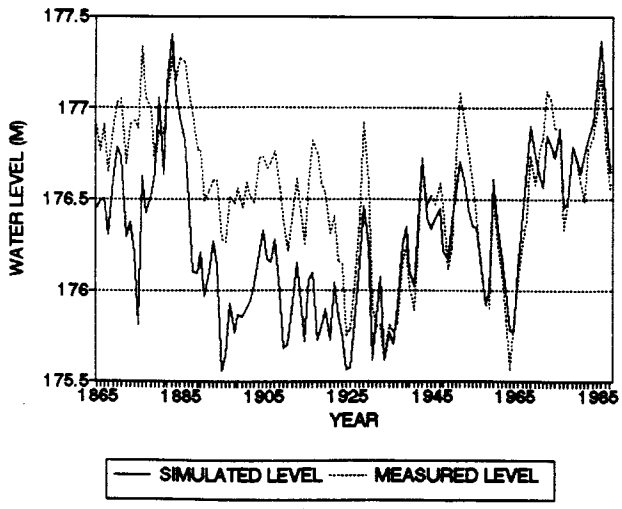

Figure 3. Great Lakes precipitation and Lake Michigan-Huron water levels.

The divergence prior to 1935 reflects navigation and sand and gravel dredging in the St. Clair River, land use changes in the basin, and changes in Great Lakes water diversions (Derecki, 1985; Quinn, 1988). The figure also illustrates the potential for lower levels in the early 1900's and in the mid-1920's than occurred in nature as well as a replication of the record high lake levels in the early 1880's.

4. CONCLUSION

An analysis of Lake Michigan-Huron water levels and upper Great Lakes precipitation indicate that the July (peak) lake levels are best correlated with an index consisting of a preceding 5-year weighted average precipitation. High index values in the early 1880's in comparison with index values in the mid-1980's, indicate that record high levels could be expected if the 1880 climatic conditions were to occur in the future. Likewise, the dominance for many years of low index values, peaking in the mid-1930's, indicates a high probability for lower than "normal" lake levels in the future. This index provides an excellent perspective on changes in the regional Great Lakes precipitation climate and the resulting lake level fluctuations. There has recently been an emphasis on selecting scenarios based upon past climate for Great Lakes studies (Quinn and Chagnon, 1989). This index could prove to be very useful for selecting such scenarios to be used in conjunction with hydrologic models for Great Lakes water level studies.

5. REFERENCES

Derecki, J.A., 1985. Effect of channel changes in the St. Clair River during the present century. J. Great Lakes Research. 11(3):201-207.

National Ocean Service, 1991. Great Lakes water levels. National Ocean Service. Rockville, MD.

Quinn, F.H., and C.E. Sellinger, 1990. Lake Michigan record levels of 1838, a present perspective. J. Great Lakes Research. 16(1):133-138.

Quinn, F.H., and S.A. Changnon, 1989. Climate scenarios for the Great Lakes Basin. Preprints, Sixth Conference on Applied Climatology, Charleston, SC, March 7-10, 1989. American Meteorological Society, Boston, 27-30.

Quinn, F.H., 1988. Great Lakes water levels, past, present, and future. Proceedings, The Great Lakes: Living with North America's Inland Waters, Milwaukee, WI, November 6, 1988. American Water Resources Association, 83-92.

Quinn, F.H., and R.N. Kelley, 1983. Great Lakes monthly hydrologic data. NOAA Data Report ERL GLERL-26.

Quinn, F.H. 1981. Secular changes in annual and seasonal Great Lakes precipitation, 1854-1979, and their implications for Great Lakes water resource studies. Water Resour. Res. 17:1619-1624.